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Evaluation of engine performance and emission with methyl ester of Karanja oil☆

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Summary Biodiesel has been considered as potential alternative to petroleum diesel with the renewable origin for the existing compression ignition engine. The main objective of the present work is evaluating performance and emission characteristics of diesel engine for various blends (B20, B40, B60, B80 and B100) of Karanja biodiesel and commercial diesel. The experimental investigation was carried out in IC (internal combustion) at variable loads and compared with conventional diesel fuel with respect to engine performance parameters i.e. brake specific fuel consumption (BSFC), brake specific power consumption (BSEC), brake thermal efficiency (η-B.Th), for varying load conditions. The results obtained indicated the better fuel properties and engine performance at B40. For all cases, BSFC reduced with increase in load. It can be observed that the BSEC for various blends is lower as compared with that of diesel fuel. The availability of oxygen in the Karanja oil methyl ester-diesel fuel blend may be the reason for the lower BSEC. Brake thermal efficiency is increased due reduced heat loss with increased in load. It was found that the emission level of CO and HC level decreased with increased in blend proportion in diesel fuel. NO_x emission increased with increase in blend proportion in diesel fuel.

Introduction

Largest single source of energy consumed by the world's population is petroleum, exceeding coal, natural gas, nuclear, hydro and renewable (Madarasz and Kumar, 2011). Oil is a critical component in the production of fertilizers, plastics and chemicals. Most experts expect worldwide oil production will peak sometime between 2007 and 2025, demand will continue to rise another 40% during the same period (Padhi and Singh, 2011). The expected 52% rise in world CO_2 emissions by 2030 and emissions of fossil fuels (including petroleum) already related to universal climate change (Tyagi and Sharma, 2012). This study purposely focuses only on biodiesel from non-edible oils but is well suited for production in a variety of sources. The dependence on finite

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Figure 1 Internal combustion engine.

energy sources controlled by dangerously few, often politically unstable countries, has unfortunately led to a cycle of crisis (Singh, 2010). Biodiesel, formally known as either methyl-ester or ethyl-ester, is a natural occurring vegetable oil or animal fat which has been chemically modified to run in a diesel engine (Yadav and Rathod, 2012). Biodiesel's many advantages compared to petroleum diesel like its renewable nature, better emissions properties, support for domestic agriculture, compatibility with existing engines and ease of manufacture (Aransiola et al., 2012). World-wide biodiesel capacity has grown to over 2.2 billion litres since commercial production began in the early 1990s (Sahoo, 2009). Biodiesel can be produced from a variety of lipid feedstock's, catalysts and alcohols and refining processes have matured, new feedstock sources have been experienced and engine technology has been constantly optimized. Today, biodiesel has much stricter definitions in the form of quality standards, established to gain wider acceptance from engine manufacturers, distributors, retailers and end users (Aliyu et al., 2012). The European Union (EU) eventually established the biodiesel standard EN 14214 in 2003, which superseded individual country standards (Sharma and Singh, 2009). Similarly, the US passed American Society for Testing and Materials (ASTM) D 6751 in 2001 which regulates 14 fuel properties including flash point, water content, Cetane, cloud point, etc. (Fukuda et al., 2009).

Methodology

In this work, the actual testing of various grades of the biodiesel developed in single cylindered four stroke water cooled engine was used as shown in Fig. 1 with 3.7 kW rated power and 1500 rpm rated speed, 85 mm bore and 80 mm stroke with compression ratio 16.5:1. It has 300 mm brake drum and 18.8 mm rope diameter. Single phase 220 V, 5 A electric and 10 LPM continuous water supplied in engine with 3 m × 2 m floor area and 10 l fuel capacity was used and compared with conventional diesel fuel with respect to engine performance parameters i.e. BSFC, BSEC, ηB.Th, for varying load conditions. Fuel measuring system consists of a fuel tank, a burette and a three way cock arrangement. Air tank fitted with orifice and water manometer. It consists of inlet, outlet piping with flow control valve, water metre, and temperature sensors is provided to measure the inlet and outlet temperature of water. Loading arrangement is provided with the Electrical brake dynamometer, which is connected to the engine through a coupling. A digital multi channelled temperature indicator measures temperature at various points.

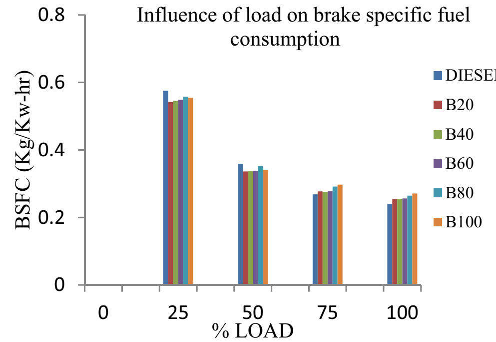

Figure 2 Variation of BSFC with load.

Results and discussions

Brake specific fuel consumption (BSFC)

The variation of BSFC at different loads is shown in Fig. 2. For all cases, BSFC reduces with increase in load. The reverse tendency in the BSFC may be due to increase in biodiesel percentage ensuring lower calorific value of fuel and may be due to a change in the combustion timing caused by the biodiesel's higher Cetane number as well as injection timing.

Brake specific energy consumption (BSEC)

Fig. 3 shows the variation of the brake specific energy consumption with load. When two different fuels of different heating values are blended simultaneously, the fuel consumption may not be reliable, since the heating value and density of the fuels are different. In such cases, the brake specific energy consumption (BSEC) will give more reliable value. The brake specific energy consumption was determined for Karanja methyl ester-diesel fuel blends as the product of the specific fuel consumption and the calorific value. It can be observed from Fig. 3 that the BSEC for various blends is lower as compared to that of diesel fuel. The availability of the oxygen in the Karanja methyl ester-diesel fuel blend may be the reason for the lower BSEC.

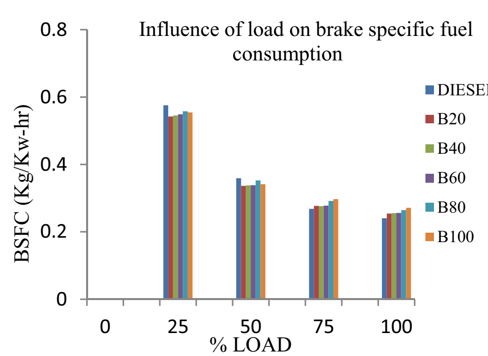

Figure 3 Variation of BSEC with load.

Table 1 Changes in emissions for fuels containing various blends of biodiesel.

S. no.	Type of emission	B20	B40	B60	B80	B100
1	HC	−12.8	−23.2	−46.5	−59.1	−70.1
2	CO	−11.2	−21.0	−32.2	−40.1	−50.0
3	NO_x	+1.1	+2.5	+3.8	+5.2	+7.1
4	SO_2	−20.2	−40.1	−60.1	−81.7	−100
5	CO_2	−14.2	−28.0	−41.2	−69.8	−78.8

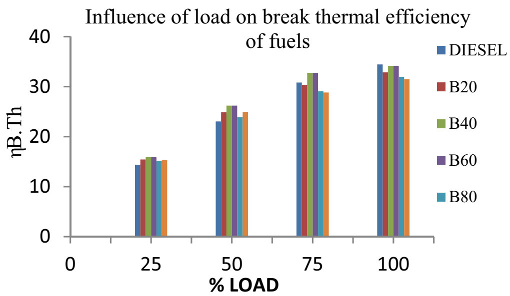

Figure 4 Variation of brake thermal efficiency with load.

Brake thermal efficiency (ηB.Th)

The variation of ηB.Th with load for different fuel blends are shown in Fig. 4. ηB.Th is increased in all cases due reduced heat loss with increased in load. The maximum efficiency obtained in this experiment was 34.16% (B40) and 33.78% (B60). But considering the viscosity B40 is the best alternative having maximum ηB.Th (34.45%). From Fig. 4, it is found that ηB.Th for biodiesel in comparison to diesel engine is a better option for part load on which most engine runs.

Emissions from various blends of biodiesel

The authors observed that the engine operation on a biodiesel blend with diesel emit lower gaseous emission than diesel fuel except NO_X, which increase to 2.5% with B40 and 7.1% with B100. With increasing of biodiesel percent in blend with diesel, it was observed that NO_x emission will enhance and reduce the CO and HC emission. CO emission is less in comparison to all blend this is due to the pure biodiesel, which have less carbon content and also due to preheating of the biodiesel, leads to decrease its viscosity and improve atomization and proper combustion and resulting in the less CO emission. Table 1 shows that all emissions with biodiesel are lower than diesel except NO_x. The life cycle analysis of biodiesel shows that the diminution in CO emission is about 21% with B40 and 50% with B100 use on per litre combustion basis. The reduction of HC is due to the oxygenated fuel of biodiesel, it leads to a more complete combustion. The higher Cetane number of biodiesel reduces delay time as well as reducing HC emissions. Thus, higher oxygen content and Cetane number of biodiesel and its various blends will reduce HC emissions when compared to conventional diesel.

Conclusions

A four stroke water cooled single cylinder direct injection diesel engine was using Karanja biodiesel blends (B20, B40, B60, B80 and B100) as fuel. All blends having Karanja biodiesel shows brake specific fuel consumption close to diesel. The lower concentration of the blends found to improve thermal efficiency. Karanja biodiesel blends give a good improvement in thermal efficiency due to the additional lubricity and oxygen content is the possible reason for it. Brake power is comparable for the all the fuel tested. The variation in the power is very less for all the tested fuels. However, at lower percentage of biodiesel in the blend small increase in brake power is observed. For various blends and preheated biodiesel BSFC and exhaust gas temperature are found higher compared to diesel at lower compression ratio. It is found that the performance of diesel engine at the 75% load is efficient. CO, CO_2 and HC emission for the biodiesel blends and preheated biodiesel is lower than that of the diesel fuel, this is due to that biodiesel is a green fuel and contain less carbon molecules. The oxygen present in biodiesel is responsible to enhance the complete combustion of the fuel, resulting in the reduction of CO and HC emissions and slightly increased NO_x emissions when biodiesel is used.

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